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RESEARCH ARTICLE

Adsorption of ammonia nitrogen by jackfruit (*Artocarpus heterophyllus*) seeds: Isotherms and kinetic modeling studies

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Abstract

Ammonia nitrogen (NH_3 - N) is one of the common and toxic species of nitrogen and excess of it in waterway causes eutrophication, decreased in dissolved oxygen and toxic to aquatic organisms. This study aims to investigate the isotherm and kinetic modeling of adsorption of ammonia nitrogen from aqueous solution by using jackfruit (*Artocarpus heterophyllus*) seed. Batch equilibrium experiments were carried out at 60 minute of contact time with initial pH value of 7. The adsorption isotherm data fitted well with Langmuir model with correlation (R^2) of 0.9809 and maximum monolayer adsorption capacitiy (Q_e) of 3.94 mg/g. Meanwhile, the adsorption of NH_3 - N follows pseudo second order with correlation (R^2) values ranges from 0.62 to 0.96 for various concentrations. Besides, the adsorption capacity obtained from experiment also has the smallest difference with calculated adsorption capacity. This suggest that the adsorption is mainly governed by chemical process involving cations sharing or exchange between the adsorbent and NH_3 - N in the solution. In conclusion, jackfruit seed can be used as adsorbent materials for ammonia nitrogen removal from aqueous solution.

***Keywords*:** Adsorption, ammonia nitrogen, jackfruit seed, isotherm

INTRODUCTION

Excessive amount of ammonia nitrogen in water bodies is one of major global environmental problem and this common problem may originate from diverse sources such as industry waste, agricultural runoff and landfill leachate. Over enrichment of nutrient in water ways lead to serious distortion on nature as it may results in depletion of dissolved oxygen, eutrophication and toxicity to aquatic lives (Yaser *et al.*, 2016).

Various traditional and conventional treatment methods have been established for years to remove ammonia nitrogen contamination such as chemical precipitation, biological treatment and adsorption. Among these methods, adsorption is considered to be the most promising and effective approach as it is economical feasible, easy in operation and environmental friendly (Ibrahim *et al.*, 2016). However, the relatively high cost of conventional adsorbent limits the usage of adsorption in wastewater treatment application. Thus, extensive studies on the renewable materials that cheaper, and abundance has been done over the past few years. The utilization of agricultural residues for adsorption process is one of the alternative technologies as it is easily available, low cost and environmental friendly. To date, the ability of agricultural waste as adsorbent for the removal of pollutant has been studied by many researchers which includes Citrus Limettioides seed and peel (Sudha *et al.*, 2015), modified empty fruit bunch (EFB) (Lee *et al.*, 2016) and watermelon rind (Ibrahim *et al.*, 2016). However, there is still limited information available on the usage of local agricultural residues as adsorbent for removal of ammonia nitrogen from aqueous solution. Hence, this research work was intended to determine the adsorption isotherms and kinetic modeling of ammonia nitrogen onto the jackfruit seed. Jackfruit (*Artocarpus heterophyllus*) seed is an oblong cylindrical or rounded in shape and is light brown in color. The jackfruit seed is composed of moisture (9.59 $\pm$ 0.1%), protein (0.09 $\pm$ 0.03%), lipid (0.03 $\pm$ 0.01%), ash (0.04 $\pm$ 0.04%), carbohydrates (93.64$\pm$ 0.73%), amylose (25.54 $\pm$ 0.38%) and amylopectine (74.46 $\pm$ 0.38%)(*dwb*) (Choy *et al.*, 2017; Rengsutthi and Charoenrein, 2011).

EXPERIMENTAL

Preparation of adsorbent

The jackfruit seeds were collected from market area located in Kota Belud, Sabah. The seeds were washed thoroughly with tap water and distilled water to remove the surface adhere impurities before dried in an oven at 40°C for 48 hours. The seeds then grounded and sieved to smaller size around 1-2 mm.

Preparation of ammonia nitrogen aqueous solution

Ammonia nitrogen (NH_3 - N) aqueous solution was used throughout the experiment and prepared by dissolving ammonium chloride (NH_4Cl) with calculated weight in 1 L of distilled water for desired concentration. The ranges of adsorbate concentrations used in this study varied between 50 to 1000 mg/L and the solution pH was adjusted by using 0.1 M of sodium hydroxide (NaOH).

Batch adsorption experiment

The experiment were conducted in batch process with initial concentration range from 50 to 1000 mg/L, initial pH 7 and 20 gram (g) of jackfruit seed. The concentration range was based on typical range of ammonia nitrogen level from landfill leachate and industrial wastewater. The concentration of solution then was analyzed at certain intervals by using UV-Vis spectrophotometer with HACH Spectrophotometer DR2010 brand at the maximum wavelength of 425 nm. The amount of ammonia nitrogen adsorbed at equilibrium, q_e (mg/g) was calculated as followed:

$$Q_e = [(C_o - C_e)V]/W \quad (1)$$

where C_o and C_e (mg/L) are the liquid-phase concentrations of initial adsorbate and equilibrium, respectively. V is the volume of the solution (L) and W is the weight of the adsorbent (g).

Adsorption isotherm and kinetic studies

The equilibrium isotherm study was conducted by adding 20 g of jackfruit seed into a 500 mg/L of ammonia nitrogen solution with adjusted pH 7.0. The residual concentration of ammonia nitrogen was analyzed until it reaches equilibrium and the data were fitted to different isotherm models; Langmuir, Freundlich, Temkin and Dubinin-Radushkevich (D-R) models.

Meanwhile, the adsorption kinetic study was carried out at various solution concentrations (50, 100, 500 and 1000 mg/L) wherein the extent of adsorption was investigated as a function of time. The experimental result then was fitted to pseudo first order, pseudo second order and intra-particle diffusion model. The best fit models for both isotherm and kinetic studies were selected based on the highest coefficient correlation (R^2) and the calculated q_e values. All experiment conducted in duplicate and the average result is calculated.

RESULTS AND DISCUSSION

Adsorption isotherm studies

Screening experiment was conducted on 40 types of potential adsorbent derived from agricultural wastes. The adsorption capacity, reoval rate and zeta potential value of each adsorbents were determined and the results obtained are tabulated in Table 1. Jackfruit seed was selected as the best adsorbent and used for further sorption studies due to the high adsorption capacity and its availability througout the years.

Table 1 Adsorption capacity and removal rate of 40 local biosorbent (Ibrahim *et al.*, 2017).

Agricultural wastes	Scientific Name	Removal rate (%)	Adsorption capacity (mg/g)	Zeta potential (mV)	Season (month)
Banana peel	Musa Acuminata	8.22	1.51	-27.4	Jan-Dec
Banana comb	Musa Acuminata	7.03	0.88	-51.37	Jan-Dec
Papaya peel	Carica Papaya	-4.96	-0.81	-32.4	Jan-Dec
Papaya seed	Carica Papaya	-17.3	-3.03	-31.6	Jan-Dec
Pomelo peel	Citrus Maxima	13.95	1.74	-29.0	Aug-Oct /Jan-March
Pineapple peel	Ananas Comosus	-39.07	-4.88	-12.4	Jan-Dec
Pineapple stem	Ananas Comosus	2.93	1.07	-14.0	Jan-Dec
Langsat (Lanzones) peel	Lansium Domesticum	28.67	3.59	-36.3	Jun-July / Nov -Feb
Langsat (Lanzones) seed	Lansium Domesticum	5.36	0.79	-48.3	Jun-July / Nov -Feb
Soursop peel	Annona Muricata	-1.96	-0.25	-22.4	March- April / June-July
Coconut coir	Cocos Nucifera	12.73	1.59	-37.9	Jan-Dec
Sugarcane bagasse	Saccharum Officinarum	3.67	1.59	-20.3	Jan-May
Corn (silk)	Zea Mays	-3.74	-4.68	-37.87	Jan-Dec
Corn (shank)	Zea Mays	-7.56	-0.95	-22.75	Jan- Dec
Corn comb	Zea Mays	-10.45	-1.56	-23.7	Jan-Dec
Corn husk leaf	Zea Mays	5.55	0.69	-20.15	Jan- Dec
Passion fruit	Passiflora Edulis	6.34	0.79	-35.1	Nov-April
Cassava peel	Manihot Esculenta	5.81	0.73	-40.11	Jan-Dec
Banana false stem (Pseudostem)	Musa Acuminata	-3.14	-0.39	-32.6	Jan-Dec
Sapodilla peel	Manilkara Zapota	-73.16	-9.32	-11.9	Jan-Dec
Limau madu (Citrus) peel	Citrus Suhuiensis	15.59	1.95	-38.05	March-April / Oct-Nov
Jackfruit peel	Artocarpus Heterophyllus	16.26	2.03	-18.03	Jan- Dec
Jackfruit seed	Artocarpus Heterophyllus	26.96	3.3702	-24.8	Jan- Dec
Areca palm	Areca Catechu	-4.32	-0.54	-31.9	Jan- Dec
Coconut mesocarp	Cocs Nucifera	-72.0	-10.08	-29.7	Jan -Dec
Honey Dew Peel	Cucumis melo var. inodorus	-5.79	-0.72	-27.2	Jan- Dec
Purple Yam peel	Dioscorea Alata	-43.05	-5.38	-47.1	Jan-Dec
Mango seed	Mangifera Indica	-78.65	-9.78	-42.07	Jan-Dec
Mango peel	Mangifera Indica	-3.74	-0.47	-26.23	Jan-Dec
Sweet potato peel	Ipomoea Batatas	6.97	0.87	-19.53	Jan-Dec
Cat's Eye (Mata Kucing) peel	Euphoria Malaiense	-52.93	-6.62	-27.1	Jan-Feb
Cat's Eye (Mata Kucing) seed	Euphoria Malaiense	-2.37	-0.36	-28.4	Jan-Feb
Moringa peel (young)	Moringa Oleifera	-76.33	-9.54	-42.33	Jan-Dec
Moringa seed (young)	Moringa Oleifera	-6.99	-0.87	-28.37	Jan-Dec
Moringa peel (mature)	Moringa Oleifera	21.09	2.64	-44.07	Jan-Dec
Moringa seed (mature)	Moringa Oleifera	-7.35	-0.92	-9.47	Jan-Dec
Breadnut stem	Artocarpus Camansi	-4.32	-0.64	-25.8	Jan-Dec
Breadnut peel	Artocarpus Camansi	10.97	1.37	-35.2	Jan-Dec
Bambangan peel	Mangifera Pajang	4.67	0.58	-21.8	May-Nov
Bitter bean (Petai) peel	Parkia Speciosa	-1.43	-0.18	-50.5	March- April/ Aug-Sept

The adsorption isotherms basically represent the adsorption equilibrium data that correspond to the relationship of mass of solute adsorbed per unit mass of adsorbent, Q_e and the solute concentration in the solution at equilibrium, C_e (Ramasamy and Krishnamoorthy, 2015). In this study, linear regression isotherm model is employed to examine the biosorption of ammonium ion onto the jackfruit seed adsorbent; Langmuir, Freundlich, Temkin and Dubinin-Radushkevich (D-R) isotherm models. Langmuir and Freundlich models usually applied to distinguish the monolayer and multilayer adsorption onto the adsorbent surface at constant temperature. Meanwhile, Temkin model used to describe the adsorption studies on which the heat of adsorption is a function of coverage. Dubinin-Radushkevich model is used to express the adsorption mechanism onto porous heterogeneous surface of adsorbent and its mean free energy (Foo and Hameed, 2010; Itodo and Itodo, 2010). In addition, several papers reported on the solid-liquid adsorption system have been using these similar models (Cengiz *et al.*, 2012; Ma *et al.*, 2011; Singh *et al.*, 2017). Table 2 summarizes the parameter constants of isotherm models for the removal of ammonia nitrogen by using jackfruit seed.

Table 2 Parameter constant for isotherm models.

Isotherm model	Parameters	
Langmuir	Q_m (mg/g)	3.9425
	B	0.0105
	R_L	0.1606
	R^2	0.9809
Freundlich	1/n	2.0708
	n	0.4829
	K_F	0.2059
	R^2	0.9690
Temkin	B	0.9105
	A	0.1027
	R^2	0.9598
Dubinin-Radushkevich	B_D	-0.0710
	Q_S (mg/g)	0.1445
	E	2.6537
	R^2	0.9285

The Langmuir isotherm model assumes that the adsorption process takes place at homogenous surface sites by monolayer sorption within the adsorbent (Jellali *et al.*, 2011). This adsorption process can only occur at a fixed number of localized sites as the sites possess equal affinity for the adsorbate, ammonium aqueous solution in this case (Vijayaraghavan *et al.*, 2006). No interaction occurred on neighboring sites of molecules adsorbed and the intermolecular forces decreased rapidly with distance (Gimbert *et al.*, 2008). This isotherm model is given by:

$$Q = Q_m b C_e / 1 + bC_e \quad (2)$$

where Q_{max} is the maximum ammonium uptake (mg/g), b is the coefficient related to the affinity between the sorbent and sorbate (L/mg) and C_e is the equilibrium concentration (mg/L). The linearization form of Langmuir isotherm model can be represented as:

$$C_e/Q_e = C_e/Q_m + 1/Q_m b \quad (3)$$

The parameter constant for Langmuir model can be obtained from the slope and intercept of a graph C_e/q_e against C_e. Fig. 1 shows the Langmuir plot of ammonia nitrogen removal by using Jackfruit seed. Based on Table 2, the value of constant b obtained is low due to the fact that jackfruit seed adsorbent has a high affinity for ammonium ion (Dawodu and Akpomie, 2014). A dimensionless constant equilibrium parameter or known as separation factor (R_L) can indicate the shape of an isotherm and this given by:

$$R_L = 1/ (1 + bC_o) \quad (4)$$

where b (L/mg) refers to the Langmuir constant and C_o is initial concentration of adsorbate. R_L values between 0 and 1 signifies a favorable adsorption, 0 indicates irreversible adsorption and value higher than 1 is unfavorable (Foo and Hameed, 2010) The R_L value obtained in this study lies between 0 and 1 and this reflects upon the adsorption process of ammonium ions onto jackfruit seed was favorable. This isotherm model was found to correlated very well to the experimental data as the regression parameter (R^2) obtained is 0.9809 as presented in Table 2.

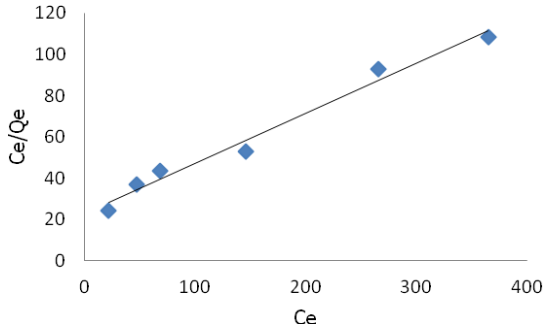

Fig. 1 Langmuir model on the adsorption of NH_3 - N by jackfruit seed (pH=7.0, C_o=500 mg/L, M=20g).

Freundlich model assumes that the adsorbent has a heterogeneous surface composed of different classes of adsorption surface sites (Doulia *et al.*, 2009). The binding strength of adsorbent surface is based on the degree of site occupation and usually surface with stronger binding sites will be occupied first (Vijayaraghavan *et al.*, 2006). Freundlich isotherm can be applied to the multilayer adsorption, with reversible adsorption and uniform energy distribution (Gimbert *et al.*, 2008). This isotherm model can be expressed by equation (5) and in linearization form equation (6) as follows:

$$Q_e = K_f C^n \quad (5)$$

$$ln\ Q_e = (1/n)\ ln\ C_e + ln\ K_f \quad (6)$$

where K_f is Freundlich constant (L/mg) and n is the capacity and intensity of adsorption.

A linear plot of ln Q_e against ln C_e was plotted to estimate the values of K_f and n value from the intercept and slope of the plot respectively as shown in Fig. 2. The value of 1/n obtained from the graph indicates the degree of non-linearity between the solution concentration and adsorption. The adsorption process is linear if the value of 1/n equal to unity and chemisorption process if the value of 1/n below unity. Meanwhile, a value above unity implies a favorable physical adsorption process(Gimbert *et al.*, 2008). The value of 1/n obtained in this study was determined to be above unity and thus indicated that the adsorption of ammonia nitrogen onto jackfruit seed is a favorable process. The graph of Freundlich isotherm model was in good agreement as it reflects high coefficient correlation value (0.9690). The value of Freundlich isotherm constants and coefficient correlation were tabulated in Table 2.

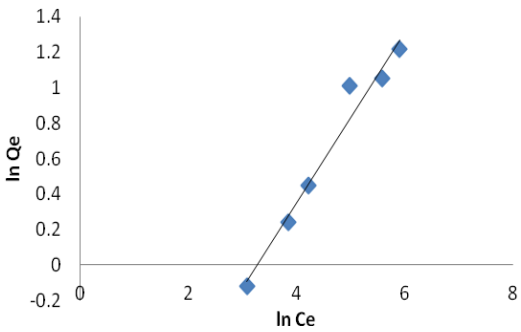

Fig. 2 Freundlich model on the adsorption of NH_3 - N by jackfruit seed (pH=7.0, Co=500 mg/L, M=20g).

The experimental data also was fitted to the Temkin isotherm model and this isotherm model considered the effects of some indirect adsorbate and adsorbent interaction. This model can be represented in Equation 7 and 8. The derivation of Temkin model equation is characterized by a uniform distribution of binding energies and in certain conditions, it can achieve maximum binding energy (Foo and Hameed, 2010).

$$Q_e = B \ln (A + C_e) \quad (7)$$

$$B = RT/b \quad (8)$$

where B (J/mol) is Temkin constant related to the heat of adsorption and A (L/mg) is the Temkin isotherm constant. Meanwhile R is the gas constant (8.314 J/mol K), b is Temkin isotherm constant and T is the temperature (K).

Fig. 3 shows a plot of Temkin model, Q_e versus ln C_e and determination of Temkin constants A and B is based on the slope and intercept of the graph. The value of B was estimated to be 0.9105 J/mol and constant A as 0.1027 L/mg. This model assumes that the despite of concentration values, heat of adsorption of all molecules decrease linearly instead of logarithmic with coverage. This decreasing trend is due to the interactions of adsorbate and adsorbent (Gimbert *et al.*, 2008). The coefficient correlation value of Temkin model was observed to be 0.9598 and lower compared to other isotherm models.

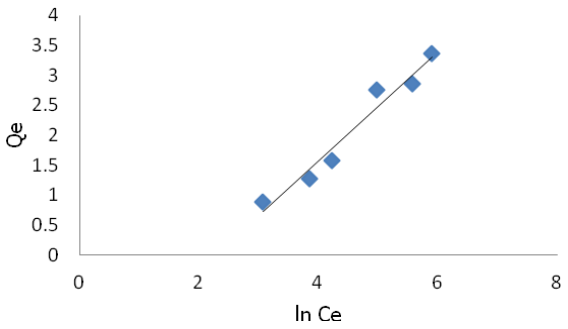

Fig. 3 Temkin model on the adsorption of NH_3 - N by jackfruit seed (pH=7.0, C_o=500 mg/L, M=20g).

The Dubinin- Radushkevich (D-R) isotherm model was applied to the experimental data in order to estimate the characteristic porosity of the adsorbent and deduce the heterogeneity of the surface energies of the adsorption process (Itodo and Itodo, 2010). This isotherm model can be expressed by equation 9 below:

$$Q_e = Q_D \exp (-BD [RT \ln (1+ 1/C_e)] \quad (9)$$

and the linearization form of D-R isotherm model is given as:

$$\ln Q_e = \ln Q_D - BD [RT \ln (1 + 1/C_e)]^2 \quad (10)$$

The mean energy of sorption, E can be estimated by equation 11 below:

$$E = 1/ (2B_D)^{1/2} \quad (11)$$

where Q_D is the D-R model constant related to the degree of sorbate sorption by the sorbent surface (mg/g) and B_D is the D-R model constant related to the free energy of sorption per mole of the sorbate as it migrates to the surface of the sorbent (mol^2/kJ^2). Meanwhile, R, T and Ce represent the gas constant (8.314 J/mol K), absolute temperature (K) and adsorbate equilibrium concentration (mg/L) respectively. Fig. 4 depict a graph of ln q_e versus $[RT \ln (1+1/Ce)]^2$ to determine the D-R parameter constants from the slope and intercept. The q_D, B_D and mean energy sorption, E values were estimated from the graph as 0.1445 mg/g, -0.0170 mol^2/kJ^2 and 2.6537 kJ/mol respectively. The coefficient correlation (R^2) of D-R model shows the lowest value compared to other isotherm model studied.

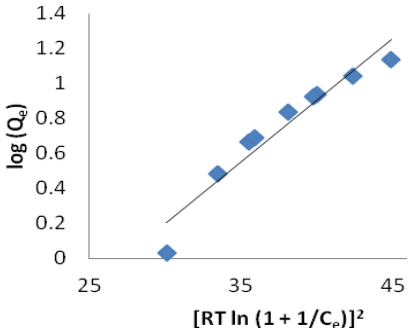

Fig. 4 Dubinin-Radushkevich model on the adsorption of NH_3 - N by jackfruit seed (pH=7.0, C_o=500 mg/L, M=20g).

Adsorption kinetic studies

The adsorption process generally possessed complex mechanism and few factors influenced the process such as solid matrix, physiochemical characteristics of the adsorbent and mass transport process (Wahab *et al.*, 2010).

Thus, by fitting the experimental data to adsorption kinetic models, the mechanism involved in the sorption process can be understand better and this is applicable for designation of large scale equipment. The mechanisms of adsorption of ammonia nitrogen onto jackfruit seed was evaluated by using three different types of kinetic models; pseudo-first order, pseudo-second order and intra-particle diffusion model.

The experimental data with different initial concentration (50, 100, 500, 1000 mg/L) of ammonium solution were employed in the adsorption kinetic studies. Table 3 and 4 illustrated the mathematical equations and kinetic rate constants for each kinetic model, respectively. The important characteristics in choosing the best fitted kinetic model is based on the value of linear regression correlation coefficient (R^2) and the calculated equilibrium adsorption capacity (q_e).

Table 3 Mathematical equations of kinetic models.

Kinetic model	Original form	Linearized form	Plots
Pseudo-first order	$dQ_t/dt = k_1(Q_e-Q_t)$	$\ln(Q_e-Q_t) = \ln Q_{e1} - k_1 t$	$\ln(Q_e-Q_t)$ vs t
Pseudo-second order	$dQ_t/dt = k_2(Q_e-Q_t)^2$	$t/Q_t = (1/k_2 Q_{eII}^2) + (1/Q_{eII})t$	t/Q_t vs t
Intra-particle diffusion	$Q_t = k_p\sqrt{t}$	$Q_t = k_p\sqrt{t}$	Q_t vs $\sqrt{t}$

Table 4 Kinetic rate constant for biosorption of ammonia nitrogen onto jackfruit seeds adsorbent.

	Initial concentration (mg/L)			
	50	100	500	1000
Experimental Q_e(mg/g)	0.07	0.29	3.37	1.34
Pseudo first order				
k_1(min^{-1})	0.01	-0.04	0.02	0.02
Calculated Q_e(mg g^{-1})	0.52	0.12	1.66	0.97
R^2	0.34	0.23	0.70	0.19
Pseudo second order				
k_2 (min^{-1})	-0.08	-0.07	0.08	0.04
Calculated Q_e (mg g^{-1})	0.04	0.21	2.97	1.69
R^2	0.85	0.96	0.92	0.62
Intra-particle diffusion				
K_p (mg g^{-1} $min^{-0.5}$)	0.14	0.14	0.21	0.14
R^2	0.92	0.92	0.80	0.92

A graph of ln (Qe – Qt) against time (t) is plotted to evaluate the fitting of experimental data to pseudo first order kinetic model. Based on Fig. 5, the pseudo-first order model did not adequately fit to the experimental data at all different concentrations as the coefficient correlation values obtained were very low and besides, the difference between the experimental and calculated Q_e values are very high as presented in Table 4.

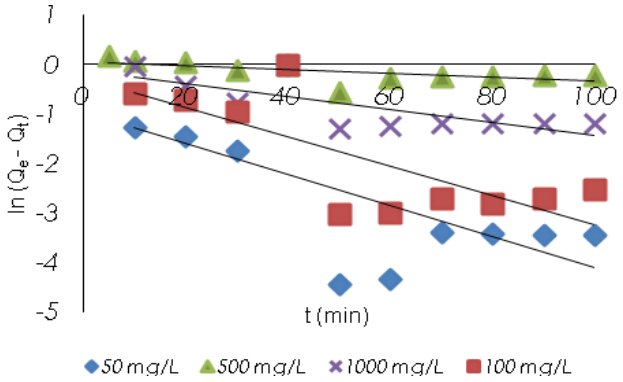

Fig. 5 Pseudo first order kinetic model.

On the contrary, the coefficient correlation (R^2) acquired from a linear plot of t/Q_t against *t* shows the highest values compared to other kinetic models as presented in Table 3. In addition, the calculated Q_e values for this kinetic model have the closest values to the experimental values. These well fitted results eventually make the pseudo second order as the best kinetic model to represent the biosorption of ammonium ions onto jackfruit seed adsorbent. Fig. 6 shows a linear plot of pseudo second order kinetic model. This model assumes that the adsorption process of ammonium ion is governed by chemical sorption and involving sharing and exchange of electrons between the adsorbent and adsorbate (Yaser *et al.*, 2016). This result is in accordance to previous studies on the biosorption of ammonium ions onto adsorbent (Chen and Chai, 2008) (Wahab *et al.*, 2010) (Liu *et al.*, 2010)

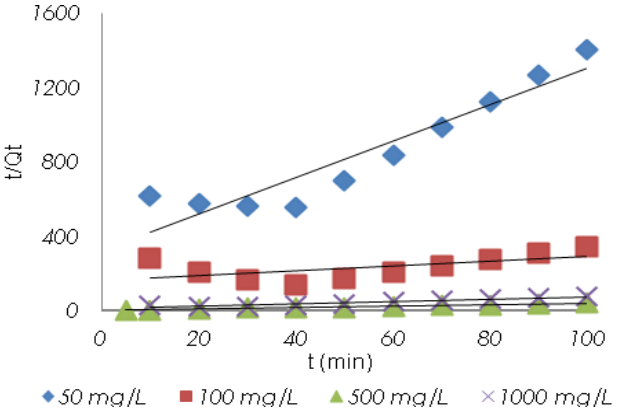

Fig. 6 Pseudo second-order kinetic models.

Intra-particle diffusion model is employed to identify the step governing involved in the adsorption process. The equation of intra-particle model can be expressed as given in Table 3. Fig. 7 depict a linear plot of Q_t versus $t^{1/2}$ at different concentrations. The slope of the graph can determine the rate constant of intra-particle diffusion model (k_p) whereas the graph intercept reflects the boundary layer effect.

The rate constant and coefficient correlation values are listed in Table 4. In this study, the linear plots at all studied concentrations did not passing through the origin and thus indicated that the intra-particle diffusion is not only the rate limiting steps involved in the adsorption of ammonia nitrogen by jackfruit seed. The linear plot depicted a multi-linearity relation and suggests that the biosorption of ammonium ions onto the jackfruit seed involves more than one process.

The earlier stage involves surface adsorption or instantaneous adsorption which correlated to the boundary layer diffusion of adsorbate meanwhile the second phase is attributed to the intra-particle diffusion occur within the pore of jackfruit seed adsorbent. The last section of the curves with null slope distinguished the final equilibrium stage where the intra-particle diffusion starts to slow down due to low adsorbate concentration in the aqueous solution (Gu *et al.*, 2011). Several studies on biosorption process onto bio-sorbent revealed to have the same adsorption stages involved (Jellali *et al.*, 2011); (Abramian and El-Rassy, 2009).

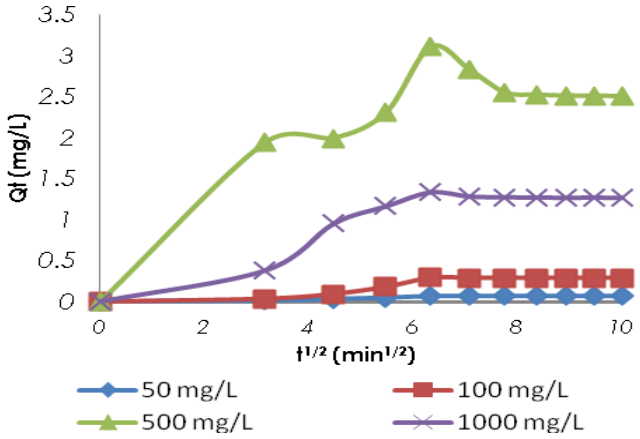

Fig. 7 Intra-particle diffusion kinetic models.

CONCLUSION

In this study, the isotherm and kinetic studies of ammonia nitrogen removal by jackfruit seed adsorbent were evaluated by fitting the experimental data obtained into few types of isotherm and kinetic models. The adsorption isotherm data fitted well Langmuir model with correlation (R^2) of 0.9809. Meanwhile, the kinetic study follows pseudo-second order model as the plot exhibited high coefficient correlation (R^2) values ranges from 0.62 to 0.96 for various concentration. Furthermore, the calculated adsorption capacity (Q_e) for this model has the closest value to the experimental values. Thus, these results indicated that the adsorption process involves sharing or exchange of cations between the adsorbent and adsorbate in the solution. This study can be concluded that ammonia nitrogen can be removed from aqueous solution by using jackfruit seed adsorbent.

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